

Update by Summer Interns and IMSA Students

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July 11, 2012

Ortec Amplifier

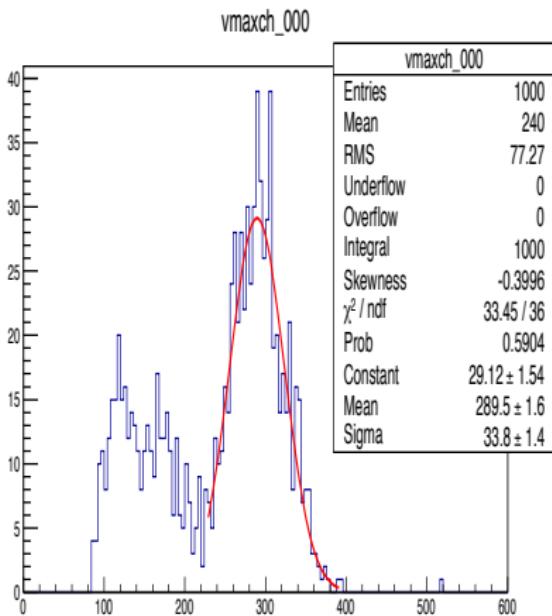


Figure: Pulse Height vs Energy

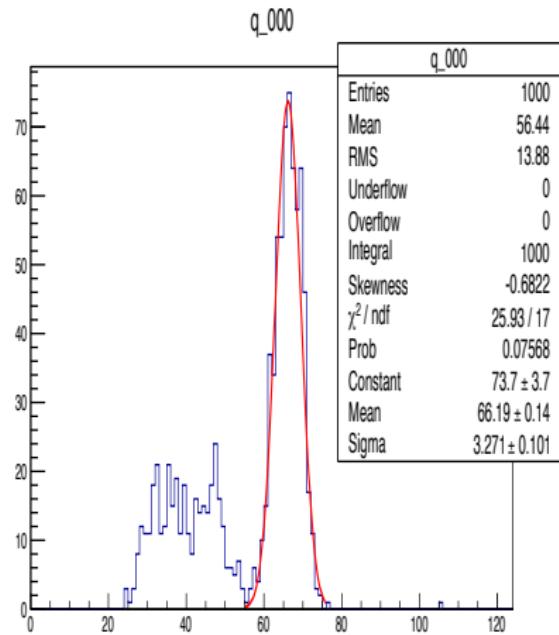


Figure: Q vs Energy

- Bias voltage for this run = -73.7 V
- Pulse height energy resolution FWHM $\sim 25\text{-}30\%$
- Integrated charge energy resolution FWHM $\sim 12\%$

Ortec vs Philips Amplifier

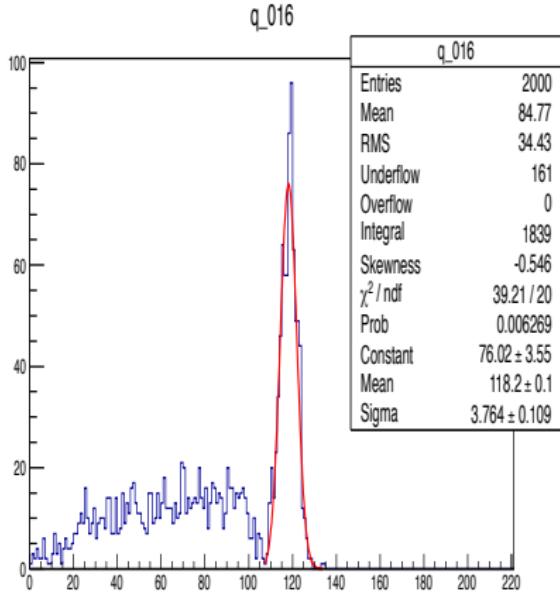
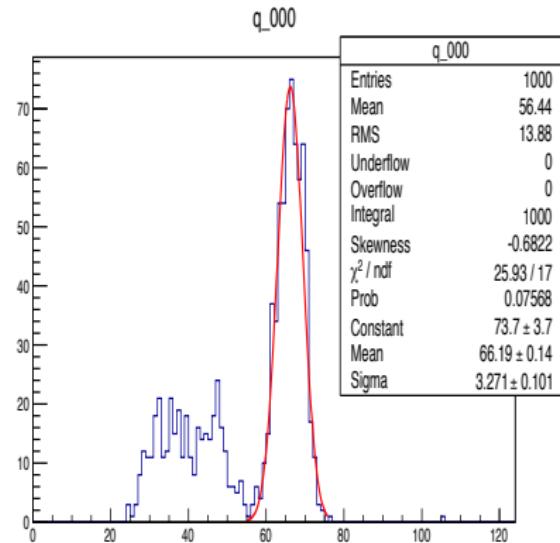


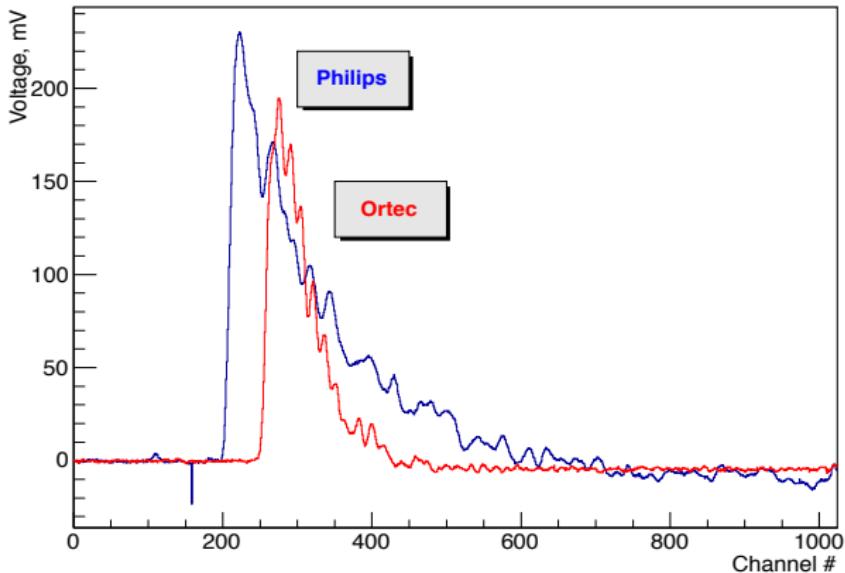
Figure: Ortec Amp

Figure: Philips Amp

- (At bias voltage = -73.7 V) Ortec energy resolution (using integrated charge) FWHM \sim 12%
- (At bias voltage = -73.6 V) Best measured Philips energy resolution (using integrated charge) FWHM \sim 7.5% , significantly better than with Ortec.

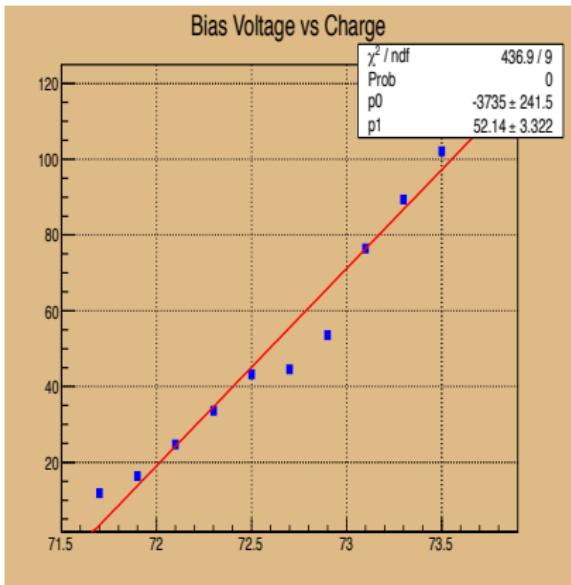
Pulse Shape Difference

Philips and Ortec amplified pulses



- Philips pulse length is almost twice that of Ortec, leading to larger integrated charge.
- Ortec has a narrower peak, so expect better timing resolution.
- Ortec has sharper leading edge for TOF measurements.

Voltage Dependence



Energy Resolution for Hamamatsu SiPM at Different Bias Voltages

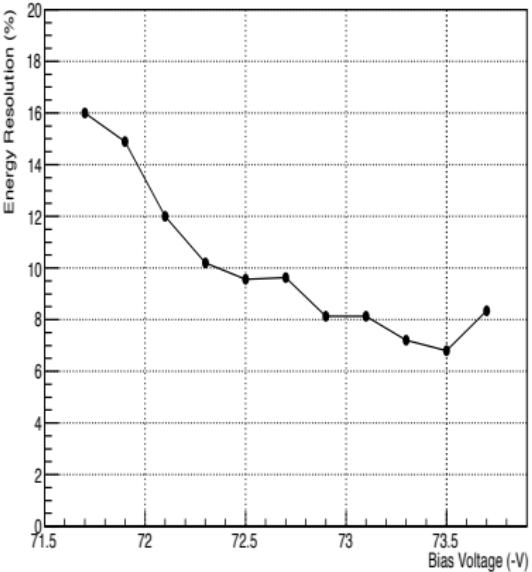


Figure: Charge vs Bias Voltage

- Charge increases linearly with bias voltage.
- Energy resolution also increases with bias voltage (max. at $\sim 7\%$)
- Improved energy resolution may be a result of photon saturation of SiPM's due to limited pixel size and number.

Conclusions

- Measured energy resolution using LYSO crystals, Hamamatsu SiPM, and Philips amplifier was 7.5%
- The best published LYSO energy resolution is 7.5 - 9% (Pepin, C.M. et al. "High efficiency of lutetium silicate Scintillators, Ce-doped LPS and LYSO crystals." Nuclear Science, Vol 51, Issue 3. 789-795)
- This increase in energy resolution may be due to SiPM behavior at high bias voltages
- Ortec's pulse shape may be better for TOF measurements.

Averaged Pulse-Shape based fitting

- Currently determining pulse start time by fitting individual events.
- To reduce the number of fitting parameters, tried using a pulse shape averaged over all events to fit individual events.
- Leaves only one degree of freedom (horizontal movement) and gives a straightforward method of determining the pulse start time.

Fitting Procedure

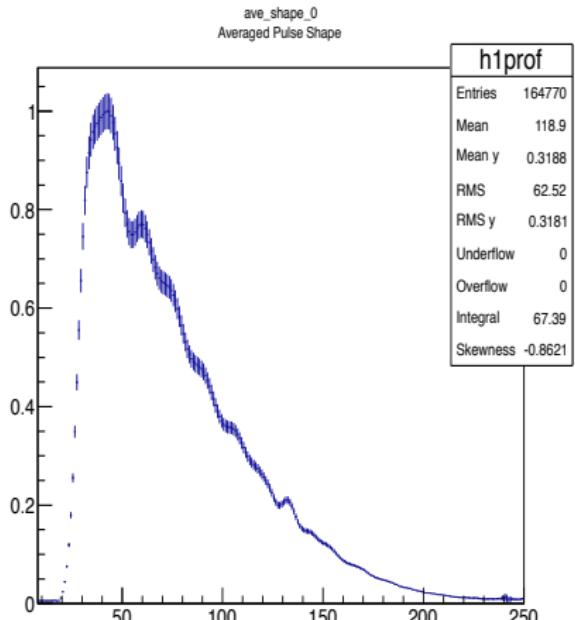


Figure: Averaged Pulse Shape (Profile Hist)

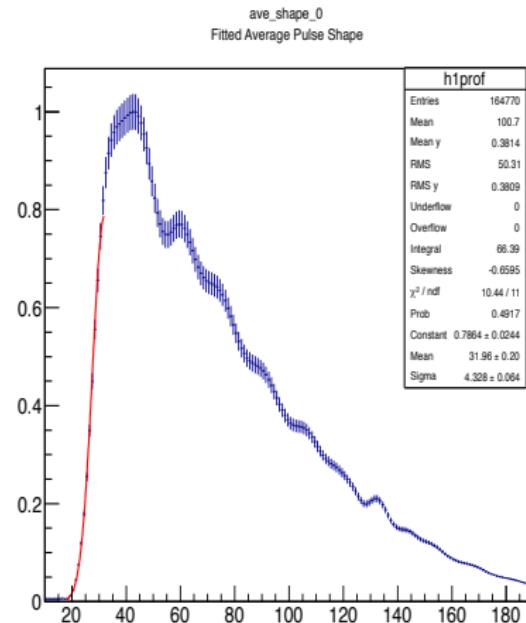


Figure: Fitted Pulse

Fit Results (Individual Event)

shape
Fitting using Averaged Pulse Shape

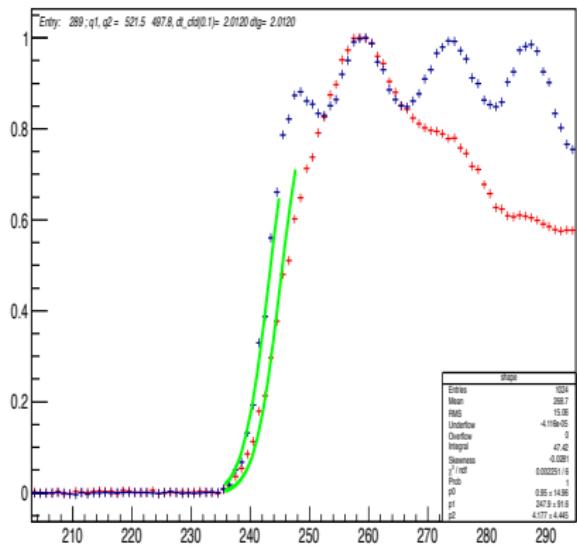


Figure: Avg. Pulse Fit

shape
Fit using Gaussian

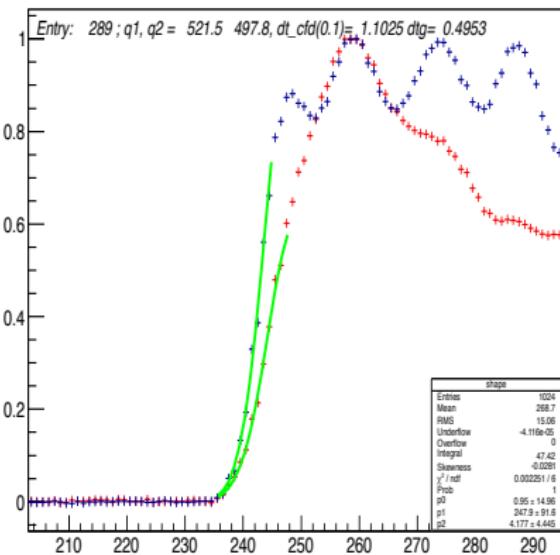


Figure: Gaussian Fit

Timing Resolution Comparison

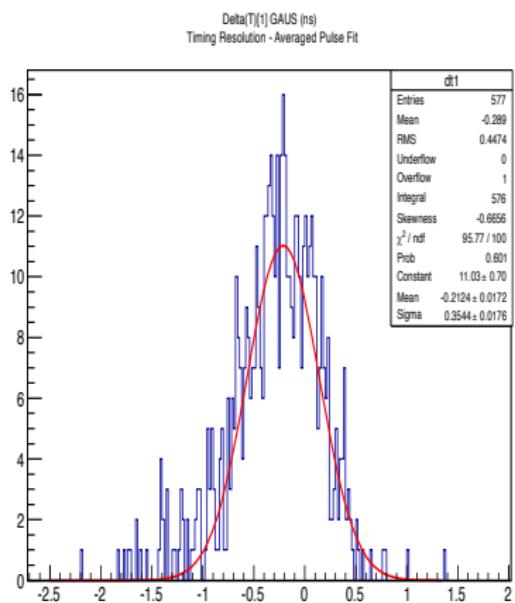


Figure: Avg. Pulse Fit

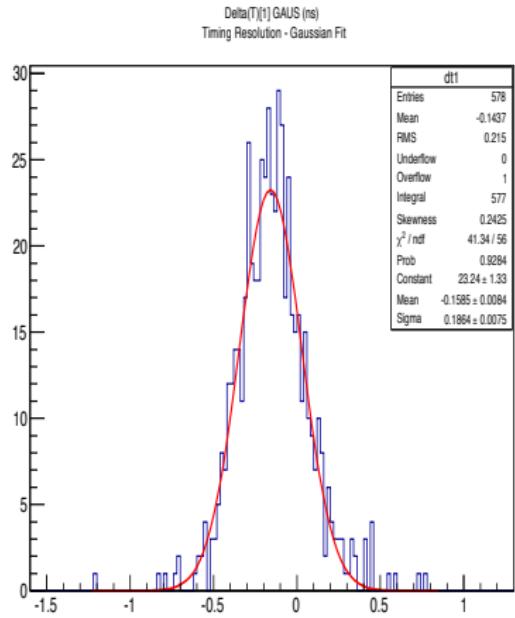


Figure: Gaussian Fit

- σ for Gaussian Fit = 186.4 ps.
- σ for Avg. Pulse Fit = 354.4 ps.

Conclusions

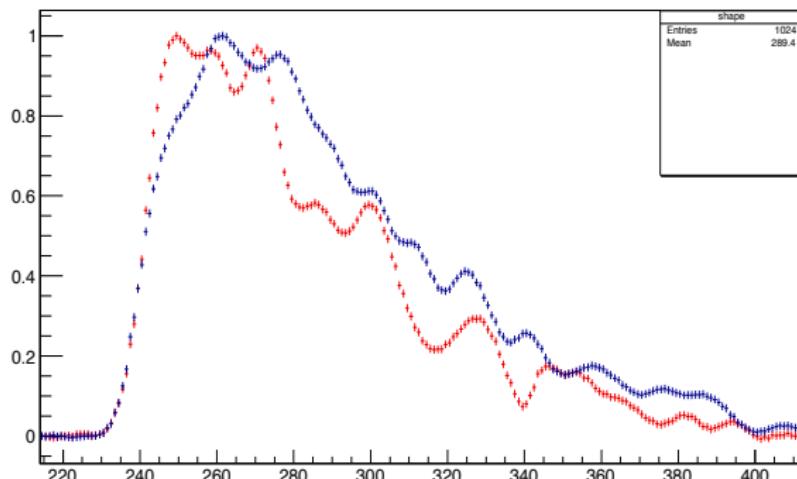


Figure: Pulse Shapes

- An assumption made in this approach was that individual event pulse shapes are stable.
- Clipping the pulse shapes lowers signal by order of magnitude and leads to instability of pulse shapes.
- Thus, a data driven approach does not work as well as fitting each event individually.

Timing Resolution across Strip-Line Board

- Pulse shapes only linear in small region.
- Linear fit procedure will be limited to using $\sim 2\text{-}35\%$
- Low statistics lead to low timing resolution across strip board.

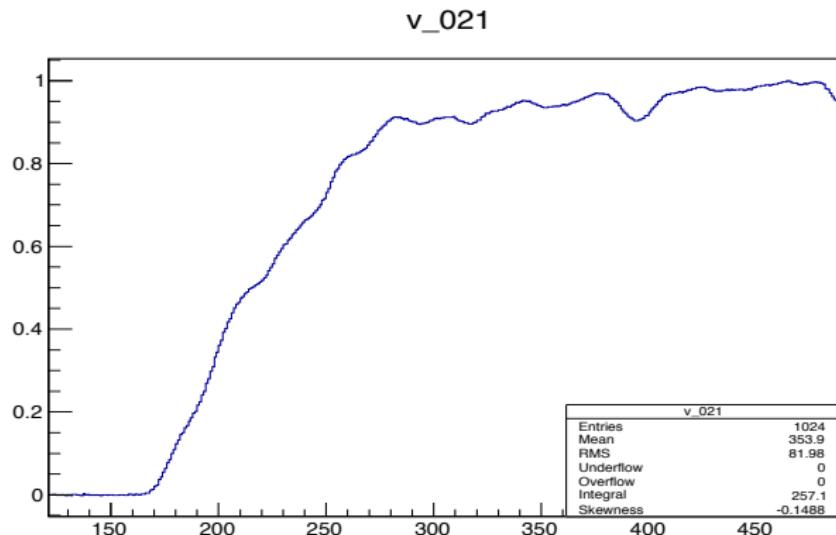


Figure: Strip Line Readout

Timing Resolution across Strip-Line Board

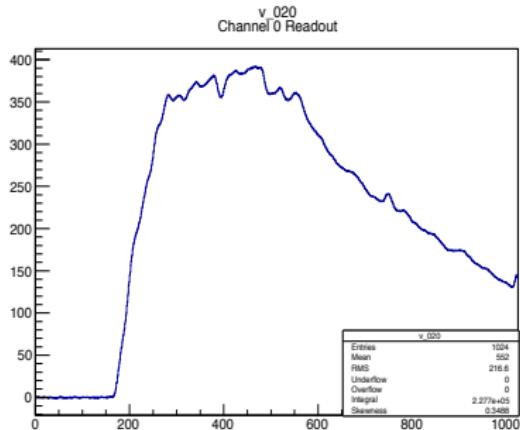


Figure: Channel 0

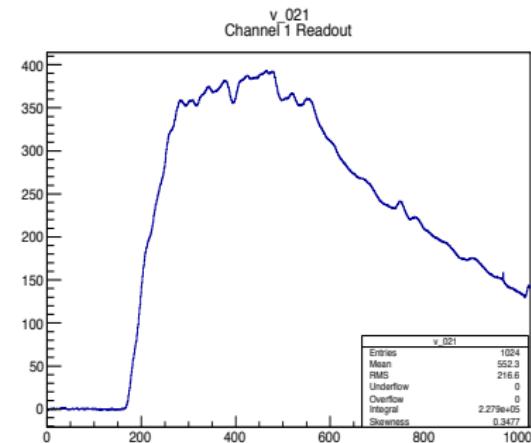


Figure: Channel 1

- Data driven fitting procedure, similar to avg. pulse fitting discussed earlier.
- Strip-Line read out from two ends: Ch 0 and Ch 1
- For individual events, the pulse shape is not distorted as it propagates across the strip-line.
- Can now utilize $\sim 2\text{-}70\%$ of readout data for fitting, increasing statistics and also resolution.

Fit Method

v_021
Fit Channel 1 with Channel 0

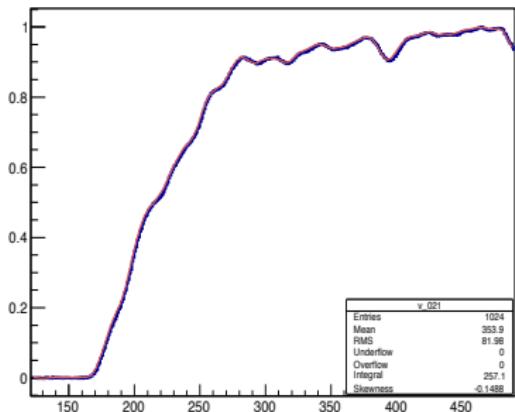


Figure: Fit Ch 1 Readout with Ch 0 Shape

v_021
Zoomed in View

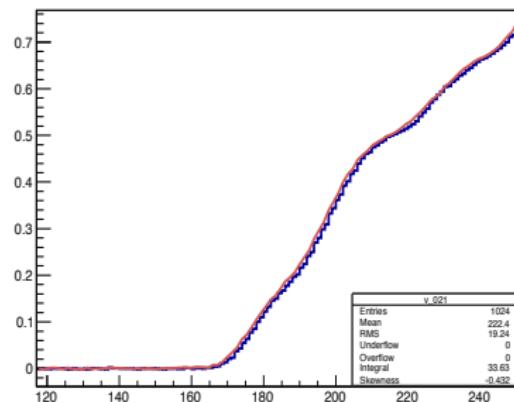


Figure: Zoomed In

- Pulse shapes readout from diff. channels for single events differ only by horizontal movement.
- Fit Ch 0 using a local parabolic interpolation.
- Extract this function and use to fit the readout from Ch 1.
- Horizontal shift gives us the timing difference across strip-line.

$$\Delta t = T[2] - T[1]$$

(1)

Results

Delta(T)[1]
Timing Resolution across Strip Line

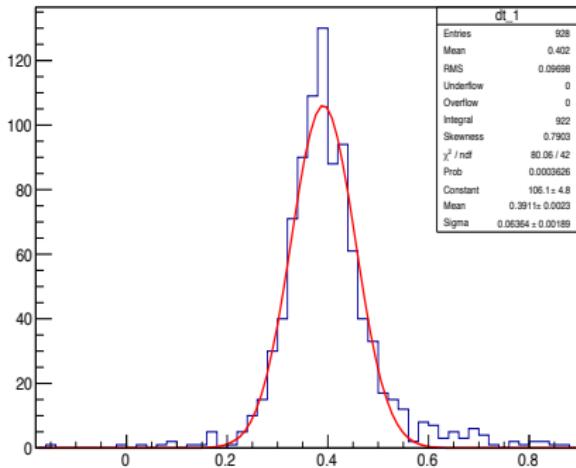


Figure: Δt (Channels)

Delta(T)[1]
Timing Resolution across Strip Line

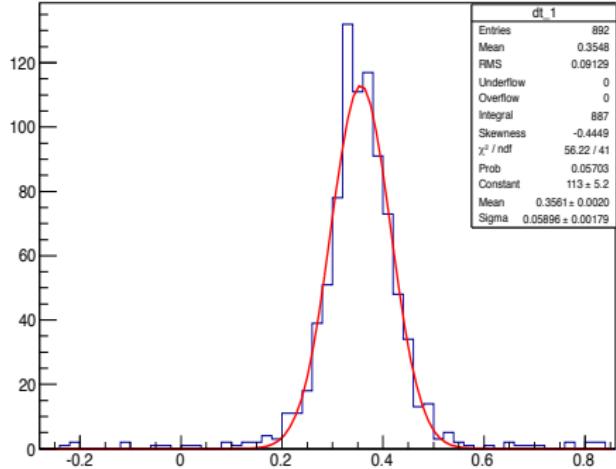


Figure: Δt (Channels)

- These are histograms of Δt for a single SiPM, where Δt is given by the horizontal fit parameter.
- Only events from the photopeak are used in determining the timing resolution.
- For Figure 1: $\sigma = 0.06364$ (in channels) \Rightarrow FWHM = 30 ps.
- For Figure 2: $\sigma = 0.05896$ (in channels) \Rightarrow FWHM = 28 ps.

Results(contd.)

- StripLine with 8 SiPM's separated by 5mm
- Resolution (FWHM) along strip line(in ps):
 - SiPM 1 : 33.37
 - SiPM 2 : 28.20
 - SiPM 3 : 50.57
 - SiPM 4 : 61.52
 - SiPM 7 : 44.68
 - SiPM 8: 31.46
 - SiPM's 5 & 6 not used in this run.

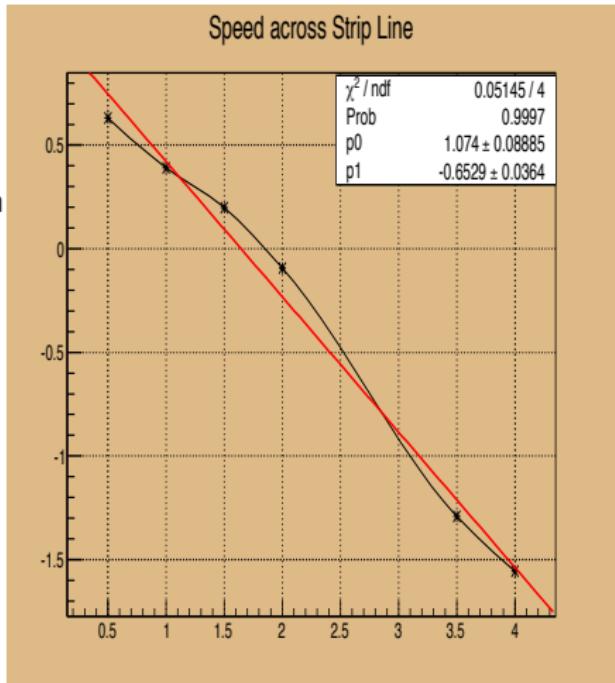


Figure: Δt Peak position (channels) vs SiPm position (in cm)

Conclusions

- Value reported at last meeting ~ 34 ps.
- Thus, by using a data driven fitting procedure, we were able to improve timing resolution across the strip board by $\sim 18\%$
- Across the stripline (length = 35mm), measure speed of pulse $\sim 0.52c$
-

$$\Delta X = \frac{\Delta t \cdot c}{2} \quad (2)$$

- Using best timing results, this translates to a resolution of ~ 2.2 mm across strip line.